GEOTECHNICAL ENGINEERING

- SOIL MECHANICS
- FOUNDATION ENGINEERING
10. A soil sample having a void ratio of 1.3, water content of 50% and a specific gravity 2.60 is in a state of
   (A) partial saturation   (B) full saturation   (C) over saturation   (D) under saturation
   Ans: B

\[ S = \frac{wG}{e} = \frac{2 \times 0.6}{1.3} = 1 \]

11. In its natural condition, a soil sample has a mass of 1.980 kg and a volume of 0.001 m³. After being
    completely dried in an oven, the mass of the sample is 1.800 kg. Specific gravity \( G \) is 2.7. Unit weight of
    water is 10 kN/m³. The degree of saturation of the soil is:
    (A) 0.65  (B) 0.70  (C) 0.54  (D) 0.61
    Ans: C

\[
\gamma = \frac{1.98}{0.001} = 1980 \text{ kg/m}^3
\]

\[
\gamma_d = \frac{1.8}{0.001} = 1800 \text{ kg/m}^3
\]

\[
\gamma_d = \frac{\gamma}{1 + w}
\]

\[
1800 = \frac{1980}{1 + w}
\]

\[
w = 0.1
\]

\[
\gamma_d = \frac{G \gamma_w}{1 + e}
\]

\[
18 = \frac{2.7 \times 10}{1 + e}
\]

\[
e = 0.5
\]

\[
S = \frac{wG}{e} = \frac{0.1 \times 2.7}{0.5} = 0.54
\]

12. A soil sample has shrinkage limit of 10% and specific gravity soils as 2.7. The porosity of the soil at
    shrinkage limit is
    (A) 21.2%  (B) 27%  (C) 73%  (D) 78.8%
    Ans: A

At shrinkage limit \( S=1 \)

\[
e = \frac{wG}{e} = 0.1 \times 2.7 = 0.27
\]

\[
\eta = \frac{0.27}{1 + 0.27} = 0.212
\]

13. Which one of the following correctly represents the dry unit weight of a soil sample which has a bulk unit
    weight of \( \gamma_b \) at a moisture content of \( w \)%?

   (A) \( \frac{w \gamma_b}{100} \) \hspace{1cm} (B) \( \gamma_b \left( \frac{100 + w}{100} \right) \) \hspace{1cm} (C) \( \gamma_b \left( 1 + \frac{w}{100} \right) \) \hspace{1cm} (D) \( \frac{\gamma_b(100-w)}{100} \)

   Ans: B
Flow Net in a Non-homogeneous Soil:
If $\alpha_1$ be the angle which the flow line make with normal in soil-1 and $\alpha_2$ be the angle in soil-2.

$$\Delta q_1 = \Delta q_2$$

$$k_1\frac{\Delta h}{\Delta s_1} \Delta n_1 = k_2\frac{\Delta h}{\Delta s_2} \Delta n_2$$

$$\therefore k_1\frac{\Delta n_1}{\Delta s_1} = k_2\frac{\Delta n_2}{\Delta s_2}$$

$$\frac{k_1}{k_2} = \frac{\tan \alpha_1}{\tan \alpha_2}$$

Questions and Answers

84. According to Darcy’s law for flow through porous media, the velocity is proportional to
(A) Effective stress  (B) Hydraulic gradient  (C) Cohesion  (D) Stability number
Ans: B

85. In a constant head permeameter with cross section area of 10 cm$^2$, when the flow was taking place under a hydraulic gradient of 0.5, the amount of water collected in 60 seconds is 600 cc. The permeability of the soil is
(A) 0.002 cm/s  (B) 0.02 cm/s  (C) 0.2 cm/s  (D) 2.0 cm/s
Ans: d

$$q = k \frac{h}{A} \quad \frac{600}{60} = k \times 0.5 \times 10 \quad \rightarrow k = 2 \text{ cm/s}$$

86. The soil profile below a lake with water level at elevation = 0 m and lake bottom at elevation=-10 m is shown in the figure, where $k$ is the permeability coefficient. A piezometer (stand pipe) installed in the sand layer shows a reading of +10 m elevation. Assume that the piezometric head is uniform in the sand layer. The quantity of water (in m$^3$/s) flowing into the lake from the sand layer through the silt layer per unit area of the lake bed is:

(A) $1.5 \times 10^{-6}$  (B) $2.0 \times 10^{-6}$  (C) $1.0 \times 10^{-6}$  (D) $0.5 \times 10^{-6}$
Ans: D
87. A soil has a discharge velocity of \(6 \times 10^{-7}\) m/s and a void ratio of 0.5. Its seepage velocity is
(A) \(18 \times 10^{-7}\) m/s  
(B) \(12 \times 10^{-7}\) m/s  
(C) \(6 \times 10^{-7}\) m/s  
(D) \(3 \times 10^{-7}\) m/s

Ans: A

\[
e = 0.5, \quad \eta = \frac{e}{1+e} = \frac{0.5}{1.5} = \frac{1}{3}
\]

Seepage velocity \(\frac{v}{q} = \frac{6 \times 10^{-7}}{1/3} = 18 \times 10^{-7}\) m/s

88. In a falling head permeability test the initial head of 1.0 m dropped to 0.35 m in 3 hours, the diameter of the stand pipe being 5 mm. The soil specimen was 200 mm long and of 100 mm diameter. The coefficient of permeability of the soil is:
(A) \(4.86 \times 10^{-5}\) cm/s  
(B) \(4.86 \times 10^{-6}\) cm/s  
(C) \(4.86 \times 10^{-5}\) cm/s  
(D) \(4.86 \times 10^{-6}\) cm/s

Ans: B

\[
k = \frac{aL}{At} \cdot \log_e \left( \frac{h_1}{h_2} \right)
\]

\[
= \frac{\pi \times 200 \times 200}{\pi \times 100 \times 100} \times \log \left( \frac{1.0}{0.35} \right)
\]

\[
= 4.86 \times 10^{-5}\) mm/s
\]

\[
= 4.86 \times 10^{-6}\) cm/s
\]

89. In a falling head permeability test, the initial head is 0.30. The head drops to 0.10 m in 40 min. The permeability of a soil sample of 0.06 m high and \(50 \times 10^{-4}\) m\(^2\) in cross-sectional area is found to be \(1.0 \times 10^{-6}\) m/s. The size of the stand pipe in cm\(^2\) is

Ans: 1.82

\[
k = \frac{aL}{At} \cdot \log_e \left( \frac{h_1}{h_2} \right)
\]

\[
1.0 \times 10^{-6} = \frac{a \times 0.06}{50 \times 10^{-4} \times 40 \times 60} \cdot \log_e \left( \frac{0.3}{0.1} \right)
\]

\[
\therefore a = 1.82 \times 10^{-4}\) m\(^2\) = 1.82 cm\(^2\)
\]

90. In a falling head permeability test the time taken for the head to fall from 27 cm to 3 cm is 10 min. If the test is repeated with same initial head i.e. 27 cm, what time (min) would it take for the head to fall to 9 cm.

Ans: 5

\[
t \propto \log \left( \frac{h_1}{h_2} \right)
\]

\[
\frac{t_1}{t_2} = \frac{\log \left( \frac{h_1}{h_2} \right)}{\log \left( \frac{h_1}{h_2} \right)}
\]
Discharge velocity \( = k_i = k \times \frac{1.2}{1.2} = k \)

Seepage velocity \( = \frac{v}{\eta} = \frac{k}{0.5} = 2k \)

104. An open ended steel barrel of 1 m height and 1 m diameter is filled with saturated fine sand having coefficient of permeability of \( 10^{-2} \) m/s. The barrel stands on a saturated bed of gravel. The time required for the water level in the barrel to drop by 0.75 m is

(A) 58.9 s  (B) 75 s  (C) 100s  (D) 150s

Ans: B

\( v = k \)

\( v = 10^{-2} \times 1 \text{ m/s} \)

\( t = \frac{d}{v} = \frac{0.75}{10^{-2}} = 75 \text{ sec} \)

105. A bed of sand consists of three horizontal layers of equal thickness. The value of Darcy’s ‘k’ for upper and lower layers is \( 1 \times 10^{-2} \) cm/sec and the middle layer is \( 1 \times 10^{-1} \) cm/sec. The ratio of the permeability of the bed in the horizontal direction to that in the vertical direction is

(A) 10.0 to 1  (B) 2.8 to 1  (C) 2.0 to 1  (D) 1 to 10

Ans: b

\( k_h = \frac{1 \times 10^{-2} \times H + 1 \times 10^{-1} \times H + 1 \times 10^{-2} + 1}{H + H + H} = 0.04 \)

\( k_v = \frac{H}{1 \times 10^{-2} + 1 \times 10^{-1} + 1 \times 10^{-2}} = 0.01428 \)

\( \frac{k_h}{k_v} = \frac{0.04}{0.01428} = 2.8 \)

106. A non-homogenous soil deposit consists of a silt layer sandwiched between a fine-sand layer at top and a clay layer below. Permeability of the silt layer is 10 times the permeability of the clay layer and one-tenth of the permeability of the sand layer. Thickness of the silt layer is 2 times the thickness of the sand layer and two-third of the thickness of the clay layer. The ratio of equivalent horizontal and equivalent vertical permeability of the deposit is ____ (GATE-2015-I)

Ans: 10.9675

\( k_h = \frac{100 \times 1 + 10 \times 2 + 1 \times 3}{1 + 2 + 3} = \frac{123}{6} \)

\( k_v = \frac{1 + 2 + 3}{100 + 10 + 1} = \frac{600}{321} \)

\( k_h = \frac{123}{6} \times \frac{321}{600} = 10.9675 \)

107. Water flows from P to Q through two soil samples, Soil 1 and Soil 2, having cross sectional area of 80 cm² as shown in the figure. Over a period of 15 minutes, 200 ml of water was observed to pass through any cross section. The flow conditions can be assumed to be steady state. If the coefficient of permeability of Soil 1 is 0.02 mm/s, the coefficient of permeability of Soil 2 (expressed in mm/s) would be ________ (GATE: CE-2016-2)
108. Seepage is occurring through a porous media shown in the figure. The hydraulic conductivity values \(k_1, k_2, k_3\) are in m/day. (GATE: CE-2016-1)

The seepage discharge \(m^3/day per m\) through the porous media at section PQ is

(A) \(7/12\) \hspace{1cm} (B) \(1/2\) \hspace{1cm} (C) \(9/16\) \hspace{1cm} (D) \(3/4\)

Ans: B

\[
k = \frac{20 + 30 + 10}{2 + \frac{3}{2} + \frac{1}{1}} = 2 \text{ m/s}
\]

\[
q = 2 \times \frac{5}{60} \times 3 = 1/2
\]

109. The soil at a site consists of two layers of thickness \(H\) each. The coefficient of permeability of the soil of 1\textsuperscript{st} layer is \(K_1\) in both horizontal and vertical directions, whereas for the 2\textsuperscript{nd} layer, it is \(K_3/2\). What will be the equivalent permeability of the two layered soil in horizontal and vertical directions. (IES:2015)

Ans:

\[
k_h = \frac{k_1 \times H + K_1/2 \times H}{2H} = k_1/4
\]

\[
k_v = \frac{H + H}{K_1 + K_3/2} = \frac{2}{3} k_1
\]

110. Find the ratio of average permeability in the horizontal direction to that in the vertical direction for a soil deposit of three layers with thickness in the ratio 1: 2: 3. The permeability of the second layer is twice that of the first and of the third is twice that of the second. (IFS:2014)

Ans: 0.65

\[
k_h = \frac{1 \times 1 + 2 \times 2 + 4 \times 3}{1 + 2 + 3} = \frac{17}{6}
\]
123. The proposed dam shown in the figure is 90 m long and the coefficient of permeability of the soil is 0.0013 mm/second. The quantity of water \( (m^3) \) that will be lost per day by seepage is (rounded to the nearest number) \( \text{(GATE: CE-1998)} \)

\[
3.8 \times 10^{-6} \times 100 \times 630 \times \frac{3}{10} \times 100 = 7.182 \text{ cm}^3/\text{s}
\]

\[
\frac{0.0013}{1000} \times 86400 \times \frac{5}{8} \times 90 = 56.862 \text{ m}^3/\text{day}
\]

Ans: B

124. The flow net around a sheet pile wall is shown in the sketch. The properties of the soil are: permeability coefficient = 0.09 m/day (isotropic), specific gravity = 2.70 and void ratio = 0.85. The sheet pile wall and the bottom of the soil are impermeable.

\[
Q = kh \frac{N_f}{N_d} = 0.09 \times 8.5 \times \frac{4}{8} = 0.38 \text{ m}^3/\text{day}
\]

Ans: B

125. The flow net around a sheet pile wall is shown in the sketch. The properties of the soil are: permeability coefficient = 0.09 m/day (isotropic), specific gravity = 2.70 and void ratio = 0.85. The sheet pile wall and the bottom of the soil are impermeable.
Final consolidation settlement does not change with drainage conditions so it is 120mm

233. A 6m thick clay layer undergoes 90% consolidation four times faster under two-way drainage as compared to one-drainage. In an identical clay layer of 15 m thickness, two-way drainage will be faster as compared to one-way drainage by

(A) 8 times  (B) 4 times  (C) 2.5 times  (D) 2 times

Ans: B

234. Root time method is used to determine
(A) T, time factor
(B) $c_v$ coefficient of consolidation
(C) $a_v$ coefficient of compressibility
(D) $m_v$ coefficient of volume compressibility

Ans: B

235. Logarithm of time method is used to determine
(A) T, time factor
(B) $c_v$ coefficient of consolidation
(C) $a_v$ coefficient of compressibility
(D) $m_v$ coefficient of volume compressibility

Ans: B

236. A saturated clay stratum draining both at the top and bottom undergoes 50 percent consolidation in 16 years under an applied load. If an additional drainage layer were present at the middle of the clay stratum, 50 percent consolidation would occur in

(A) 2 years  (B) 4 years  (C) 8 years  (D) 16 years

Ans: B

$\frac{16}{4} = 4$ years

237. Identical surcharges are placed at ground surface at sites X and Y, with soil conditions shown below and water table at ground surface. The silty clay layers at X and Y are identical. The thin sand layer at Y is continuous and free-draining with a very large discharge capacity. If primary consolidation at X is estimated to complete in 36 months, what would be the corresponding time for completion of primary consolidation at Y?

(A) 2.25 months  (B) 4.5 months  (C) 9 months  (D) 36 months

Ans: C

$\frac{36}{4} = 9$ months
633. A singly under-reamed, 8-m long, RCC pile (shown in the adjoining figure) weighing 20 kN with 350 mm shaft diameter and 750 mm under-ream diameter is installed within stiff, saturated silty clay (undrained shear strength is 50 kPa, adhesion factor is 0.3, and the applicable bearing capacity factor is 9) to counteract the impact of soil swelling on a structure constructed above. Neglecting suction and the contribution of the under-ream to the adhesive shaft capacity, what would be the estimated ultimate tensile capacity (rounded off to the nearest integer value of kN) of the pile?

\[
20 + \frac{\pi}{4} (0.75^2 - 0.35^2) \times 9 \times 50 + 7.6 \times \pi \times 0.35 \times 0.3 \times 50 \\
= 300.86 \approx 301 \text{ kN}
\]

Ans: D

(A) 132 kN  (B) 156 kN  (C) 287 kN  (D) 301 kN

634. A group of 16 piles of 10 m length and 0.5 diameter is installed in a 10 m thick stiff clay layer underlain by rock. The pile-soil adhesion factor is 0.4; average shear strength of soil on the side on the sides is 100 kPa; undrained shear strength of the soil at the base is also 100 kPa. The base resistance of single pile is

(A) 40.00 kN  (B) 88.35 kN  (C) 100.00 kN  (D) 176.71 kN

Ans: D

\[
Q_p = cN_e \times A \\
= 100 \times 9 \times \frac{\pi \times 0.5^2}{4} \\
= 176.71 \text{ kN}
\]

635. A group of 16 piles of 10 m length and 0.5 diameter is installed in a 10 m thick stiff clay layer underlain by rock. The pile-soil adhesion factor is 0.4; Average shear strength of soil on the side on the sides is 100 kPa; Undrained shear strength of the soil at the base is also 100 kPa. Assuming 100% efficiency, the group side resistance is

(A) 4795.0 kN  (B) 10000.0 kN  (C) 10053.1 kN  (D) 20106.0 kN

Ans: A

Capacity as individual action:

16\[176.71 + \pi \times 0.5 \times 10 \times 0.4 \times 100\] = 12880 kN

Let S be the side of Square

\[
S = 3a + 0.5 \\
4[3a + 0.5] \times 10 \times 0.4 \times 100 + (3a + 0.5)^2 \times 100 \times 9 = 12880 \\
a = 0.832 \text{ m}
\]

Group side resistance =4[3 \times 0.83238 + 0.5] \times 10 \times 100 \times 0.4 = 4795 kN

636. A group of sixteen piles arranged in a square pattern is to be proportioned in a deposit of soft saturated clay. Assuming the piles to be square (with side 300 mm) and 12 m long work out the spacing of piles for
100 percent efficiency of pile group. Take mobilization factor of 0.8 and consider both point and skin friction. (IFS-2003)

Ans:

\[ Q_u = 16(9 \times c \times 0.3 + 0.3 + 0.8 \times c \times 4 \times 0.3 \times 12) = 197.28c \]

\[ Q_u = 9c \times B^2 + c \times 4B \times 12 = (9B^2 + 48B)c \]

\[ 9B^2 + 48B = 197.28 \]

\[ B = 2.72m \]

\[ B = 3s + 0.3 \rightarrow s = 0.8m \]

637. For the soil profile shown in figure below, the minimum number of precast concrete piles of 300 mm diameter required to safety carry the load for a given factor of safety of 2.5 (assuming 100% efficiency for the pile group) is equal to

(A) 10  (B) 15  (C) 20  (D) 25

Ans: C

\[ Q = \frac{\pi \times 0.5^2}{4} \times 9 \times 150 + \pi \times 0.3 \times 10 \times 0.57 \times 100 = 632.6 \]

No. of Piles = \[ \frac{5000}{632.6} \times 2.5 = 7.9 \times 2.5 \]

\[ = 19.75 \text{ say } 20 \]

638. What is the ultimate capacity in kN of the pile group sown in the figure assuming the group to fail as a single block?

(A) 921.6  (B) 1177.6  (C) 2438.6  (D) 3481.6

Ans: D

\[ (1.2 + 0.4)^2 \times 9 \times 40 + 4(1.2 + 0.4) \times 10 \times 40 = 3481.6 \text{ kN} \]

639. The load carrying capacity of an individual friction pile is 200KN. What is the total load carrying capacity of a group of 9 such piles with group efficiency factor of 0.8?